JATROPHA CURCAS, AN ALTERNATIVE ENERGY RESOURCE FOR BARREN AREAS OF INDONESIA.

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Abstrak

Minyak dari tanaman Jatropha Curcas ditinjau sebagai alternatif pengganti bahan bakar minyak konvensional diteropong dari sisi sosial ekonomi dan perspektif pembangunan perdesaan. Penanaman Jatropha Curcas diseluruh daerah kritis dibawah program penghijauan dapat menjadi aset national yang produktif. Areal penanaman bisa menyesuaikan dana yang tersedia.
Minyak dari tanaman ini dapat mendukung di berbagai bentuk kebutuhan energi seperti untuk memasak, keperluan industri, transportasi dan penerangan tradisional maupun kelistrikan. Jenis energi ini memancarkan amat sedikit polusi dan penanaman massal menawarkan kemungkinan mitigasi CO_2 dan memperbaiki tampilan daerah kritis di Indonesia. Namun kegunaan lahan kritis untuk penanaman Jatropha Curcas akan tergantung pada kebijakan pemerintah terkait dengan skenario penganekaragaman supply energi untuk masa depan, pembangunan perdesaan dan keterbatasan lingkungan.

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Abstract.

Curcas oil as an alternative of conventional oil is viewed from the socio-economic in rural development perspectives. The energy-specie tree plantation on the critical land of Indonesia under rehabilitation program will create a productive national asset. The production capacity is flexible so it is easily match to the existing funding. This bio-energy provides a contribution to all energy markets (heat power, transport fuel, traditional lighting and energy for cooking). Emit less noxious-gas emissions into the atmosphere and might give a share to mitigate CO_2 and to improve the environment look in the barren areas of Indonesia. However, the real usable amount of this critical land for energy crops will depend on adopted policies concerning diversification of future energy supply scenario, rural development and environmental constraints.

Keyword: bio-diesel, critical land, curcas oil, jatropha curcas, poverty, rural development

1. INTRODUCTION.

The growth of energy demand is driven by:

- Population growth that means increase demand for home lighting.
- Industrial growth to fulfill the growing need for food and good.
- Trading growth means increase transport.

This means energy primer will be needed: - for electricity, that closed related to education; - for cooking, that closed related to human health; and - for transport, that closed related to trading
Fast increase of population and limited natural resource will lead to unsecured national energy supply for the future. Therefore, need to construct an economically attractive and

environmentally benign strategy for energy security. One area in which scientific works have lead to a conclusion of practical relevance is the use of non-edible bio-oil in reciprocating engines of a small electric generation and in gas turbine engines of vehicle leads to some serial researches around the world and an effort to develop a planting system of energy-species trees to raise its seed yield. There are several energy-species trees, see **Table 1**. One of them is jatropha curcas.

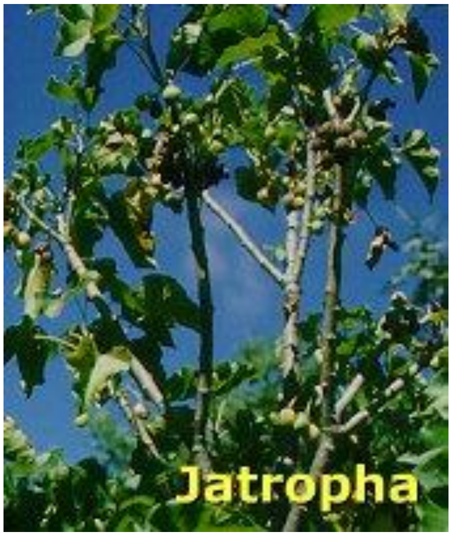
Table 1 Several possible energy species with potential to grow in Malagasy.
Source: Gaydou et al. (1982)

	Crop production tons/ha	Fuel production per ha tons/ha	Energetic equivalent kwh/ha
Elaeis Guineensis	18–20	3.6–4	33,900–37,700
Jatropha Curcas	6–8	2.1–2.8	19,800–26,400
Aleurites Fordii	4–6	1.8–2.7	17,000–25,500
Saccharum Officinarum	3.5	2.45	16,000
Ricinus Communis	3–5	1.2–2	11,300–18,900
Manihot Eaculenta	6	1.02	6,600

Jatropha curcas is a small tree up to 6-8 m height and belongs to the euphorbia family. The genus Jatropha contains approximately 170 known species (Henning, 2004). The plant is monoecious and flowers are unisexual. Jatropha curcas is not self propagating. It has to be planted. Pollination is by insects. After pollination, a trilocular ellipsoidal fruit is formed. Jatropha curcas is a native tropical of America, but grows almost anywhere: on gravelly, on the poorest stony soil, sandy and saline soils. It grows well on marginal land with 600 mm of rainfall per year, however, it still grows in hot climate with rainfall of 2000mm. It withstands long drought period. Jatropha starts producing seeds within 12 months but reaches its maximum productivity after 4 to 5 years. The life-span of the Jatropha curcas plant is more than 50 years (Henning, 2004).

Fig. 1 left: Seeds of Jatropha curcas.
The exocarp remains fleshy until the seeds are mature. The blackish, thin shelled seeds are oblong. The seeds are black, 18 mm long (range:11–30) and 10 mm wide (range:7–11).
A kilogram consists of 1375 seeds in average.

Other potential energy-species tree is Pongamia Pinnata, see **Fig. 1 right**: fruits of Pongamia Pinnata. The seeds become mature when the capsule changes from green to yellow after 2-4 months from fertilization. These seed are also named as physics nut.



Photographs is taken from Becker K and H.P.S.Makkar (1999).

Seed contains a dangerous toxalbumin curcin, rendering it potentially fatally toxic for human consumption. The poisoning is irritation with acute abdominal pain and nausea about 1/2 hour following ingestion. Diarrhea and nausea continue but are not usually serious. Depression and collapse may occur, especially in children. Four to five seed are said to have caused death, but the roasted seed is said to be nearly innocuous. The seeds are considered anthelimintic in Brazil, and the leaves are used for fumigating houses against bed-bugs. The ether extract shows antibiotic activity against Styphylococcus aureus and Escherichia coli (Reyadh, 2004).

Other advantages are the organic matter from the shed leaves enhances earth-worm activity in the soil around the root-zone of the plants, which improves the fertility of the soil. Jatropha curcas can be grown as a quick yielding plant. Each inflorescence yields a bunch of approximately 10 or more fruits. The latex of Jatropha contains an alkaloid known as "jatrophine" which is believed to have anti-cancerous properties. It is also used as an external application for skin diseases, wound healing, rheumatism and for sores on domestic livestock. The roots are reported to be used as an antidote for snake-bites. Bark, fruit, leaf, root, and wood are all reported to contain HCN. The seeds can be burned like candlenuts (Watt and B.Brandwijk, 1962). According Ochse (1980):"the young jatropha leaves may be safely eaten, steamed or stewed". They are favored for cooking with goat meat, said to counteract the peculiar smell. The juice of the leaf is used as an external application for piles.

Duke and Atchley (1984) and Reyadh (2004) give the chemical composition of the jatropha curcas seed. It contains:- Moisture 6.20 %; - Protein 18.00 %; - Fat 38.00 %; - Carbohydrates 17.00 %; - Fiber 15.50 %; - Ash 5.30 %. The oil content is 35 – 40% in the seeds and 50 – 60% in the kernel. Therefore the seeds can be extracted to get raw oil named as curcas oil and by transesterification process the raw oil is converted to be a good quality bio-diesel. The bio-residue (after extraction) is named as oil cake, which is rich in nitrogen, phosphorous and potassium and makes it excellent for organic manure. Curcas oil is a better alternative for kerosene lamp as it burns without emitting smoke.

2. WHICH PART OF INDONESIA IS GOOD FOR PLANTING JATROPHA CURCAS?

Rain fall map of Indonesia is given in **Fig. 2**. The critical land of Indonesia is given in **Fig. 3,** see Herliyani Suharta (2004a and 2004b). The total is 19,663,343 hectares. The rehabilitation program is 3,921,553 hectares that covers only 20% of the whole critical lands.

The areas that posses a hot climate, low rain fall and have wider critical land are East Java (1,302,379 ha), East Nusa Tenggara (1,356,757 ha), West Nusa Tenggara is (278,698 ha) and South Sulawesi (1,032,802 ha). These areas therefore are considered appropriate for planting Jatropha Curcas.
The economical situations of these areas compare to other provinces of Indonesia are given in **Fig. 4a** and **Fig. 4b.** The villagers' survival depends on what they can grow in their lands.
The land of West Timor, East Nusa Tenggara, for example, is black rock with a thin fertile soil on the crevices. It could provide corn as the main staple for the people, but seldom nothing lefts over to sell. This thin soil might produce a little more than just harvests corn. Planting Jatropha Curcas as agro forestry crop gives a chance to get bio-oil, adds to the capital stock of farmers, creates green view in the critical lands and provides a CO_2 sink facilities. The planting, its maintenance, harvesting, cracking the dry fruit to get the seeds and its primary processing through expellers to extract its oil content might create jobs and income for the people.

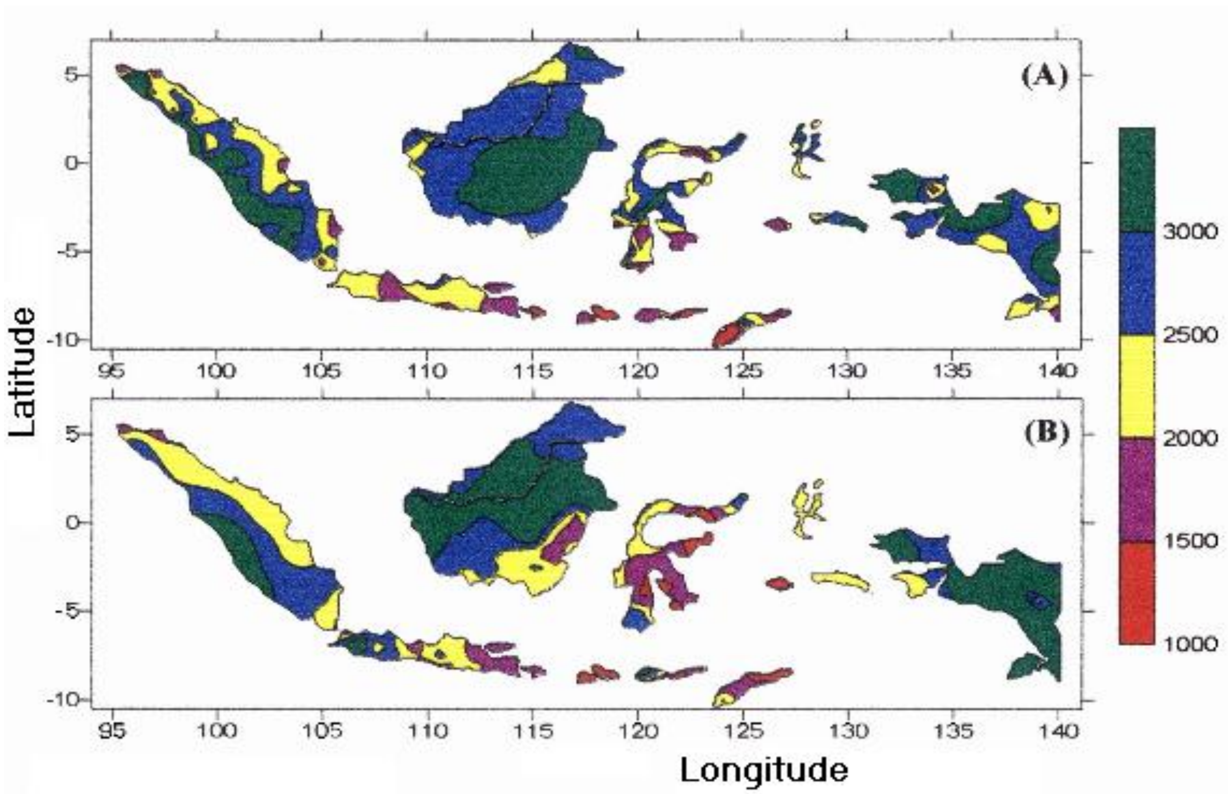


Fig. 2 Yearly average rain fall in Indonesia (mm) in the period:
(A) 1931-1960 (B) 1960-1990
Source: Rizaldi Boer, Bambang DD, Perdinan, Delon and Rini Hidayati (2003), *"Dampak Perubahan Iklim dan Tataguna Lahan Terhadap Sumberdaya Air ADS Citarum",*
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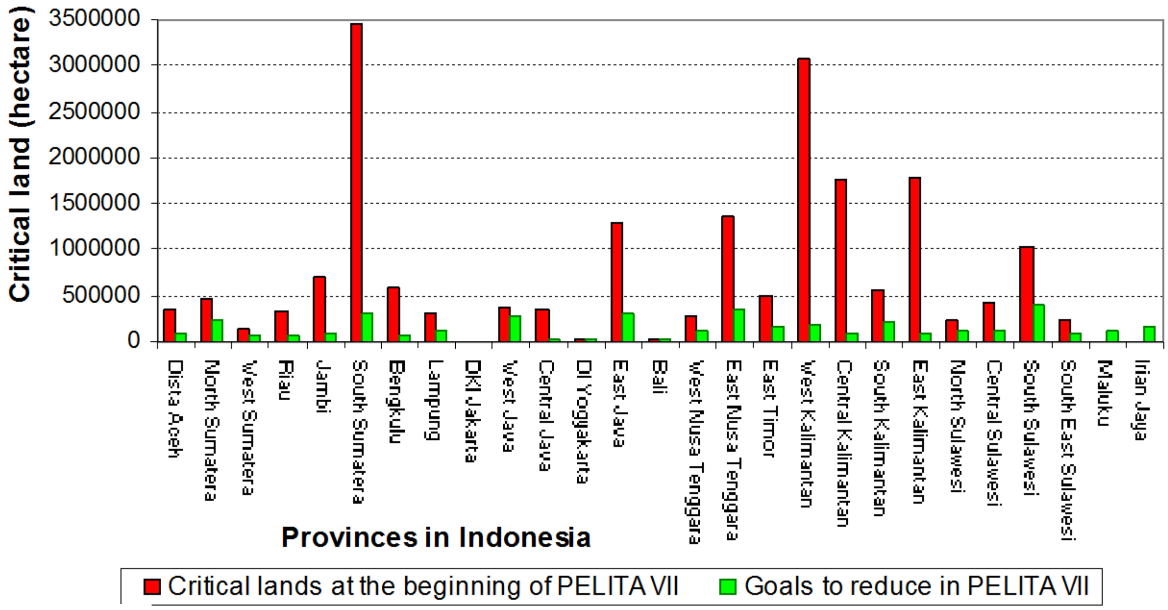

Fig. 3 The critical lands by provinces and the rehabilitation program to reduce critical lands of Indonesia in the 5-years development period: 1999 - 2003 **(PELITA VII)**
Critical lands in Kalimantan is 7.179 million hectares in total.
Source: Statistik Indonesia 1999, BPS (2000, p 217).

3. JATROPHA CURCAS OIL.

The biggest producer of curcas oils is India (385000 tons/year) then Brazil and Thailand.
The curcas oil contains 21% saturated fatty acids and 79% unsaturated fatty acids.
The Sayari Expeller has been developed by FAKT Consulting Engineers to extract the oil from the jatropha seed in Nepal. It was designed using iron sheets instead of cast iron to limit the weight of the heaviest parts to 40 kg. It is now built by VYAHUMU Trust, Morogoro, Tanzania and by POPA in Harare, Zimbabwe (Henning, 2004)
Curcas oil as obtained from the expeller requires thorough cleaning as this point related to a maintenance problem and to avoid a gumming in the fuel injectors of the engine.

The standard specifications of jatropha oil and of diesel oil are given in **Table 2a** and **Table 2b.** Curcas oil has a very high saponification value therefore it is being extensively used for making soap in some countries. It contains no aromatic substances associated with petroleum diesel. Its higher cetane number indicates potential for higher engine performance. Its high viscosity represents superior lubricating properties increases functional engine efficiency. Its higher flash point makes them safer to store. Its molecules are simple hydrocarbon chains and contain higher amount oxygen (up to 10%) that ensures more complete combustion of hydrocarbons leading to

cleaner and healthier alternative to conventional diesel. Curcas oil reduces emission of particulate matter by 40%, unburned hydrocarbons by 68%, carbon monoxide by 44%, sulphates by 100%, polycyclic aromatic hydrocarbons (PAHs) by 80%, the carcinogenic nitrated by 90% on an average (George Francis and K. Becker, 2004).
It can be easily blended in any proportion without fear of phase separation (Venkatachalam, 2003). Curcas-diesel blend (20% curcas and 80% petroleum diesel) has been successfully tested in 7.5 hp diesel engine for irrigation purpose and in a tractor for farm operation for six month test without any modification of engine, see Vedamuthu and Rengasamy (2003). Program to establish transesterification process to improve the quality and performance of curcas oil is underway.

Transesterification process.

The majority of bio-diesel produced today is done by transesterification process in order to remove its free fatty acids and making it more fluidly by adding alcohol (such as methanol) in the presence of catalyst in order to chemically break the molecule of the raw bio-oil into methyl esters, with glycerol as a by-product. The process requires low temperature, low pressure and relatively short reaction time and direct converted to methyl ester without intermediate step.
A commercial scale of transesterification has been developed in Austria. It is a continuous process in which methanol is mixed with the raw oil and potassium hydroxide is added as catalyst. After mixing and a chemical exchange are completed, the oil separates into free glycerol and methyl esters. The glycerol, which is heavier than the esters, is drained from the bottom of the tank and the remaining traces of alcohol and potassium hydroxide are washed with water for purification the methyl ester product. This process transforms 98% of the raw oil to a valuable bio-diesel that means no gums, free of fatty acids, no water and no solid particles.
The processing plant is financed by a revolving fund that initially capitalized by the Austrian Government. The agricultural producers are represented by the Union of Agricultural Cooperatives (UNAG) that in charge of the cultivation of the jatropha curcas seeds. PETRONIC has the overall control and to marketing the final product that will be accomplished through their own group of petrol stations. The methyl ester will be sold as a mix with conventional diesel (Foidl N and Eder P, 1997).

Tests have shown this bio-diesel has similar horsepower, torque and haulage rates as conventional diesel. They get the same mileage at nearly the same power and consumption.
A kilogram of diesel oil will equal to 1.05 kg of curcas oil, but they found the engine fuel consumption increases 10 percent by volume as compared to conventional diesel oil even though the engine exhaust appears clean during visual inspection. It has not been possible to ascertain the cause whether due to solid impurities or resinous material in the oil.

Other bio-diesels can be made of soybean oil, rice bran oil, sunflower oil, mohua oil, rapeseed oil, karanjia oil, peanut oil, linseed, olive oil, cottonseed oil and crude palm oil.
Curcas oil properties compare to other non-edible oils is given in **Table 3.**

Kimia Farma, Semarang, Indonesia (2004) produced ricinus communis oil that also named as castor oil. Their oil is classified as grade one of the International castor oil standard. Its high

viscosity makes this oil famous for engine lubricant. Its boiling point is 285°C, while its freezing point is – 4°C. This physical characteristic gives a chance of its use in cold climate.
Note to compare: coconut oil freezing point is 8°C and its boiling point is 200°C.
Good Year use castor oil in the process to produce tire to improve its elasticity by 2 %. The use of this oil in liquid paint will shorten drying period and give a better colour.
Kimia Farma has experiences in the extraction of castor oil. They have tested:

- A small extraction process left 14-16% "fat residue" and need a lot of human energy.
- The Mechanical Screw Press that left 5-8% "fat residue".
- Solvent Extraction Process that left 0.5-1% "fat residue".

The oil cake (black colour like soil) is exported to Thailand and it is used as organic manure. Their machine could be use to extract oil from various seeds of energy-species tree.

Their ricinus communis plantation gives 700 kilograms seeds per hectare per year, in which 300 seeds weight 100 grams. If a hectare has 2500 trees (4 m^2 / tree), this means one trees give 280 fruits in average per year. 3600 tons seeds give 1000 tons castor oil. The price of Ricinus Communis seeds nowadays is Rp2200. The local price of castor oil is Rp10000 - Rp12000 / kg. In 2004, they produced 125 tons castor oil. It was exported to Netherland (45 tons), USA (15 tons) and the rest for local need. To increase castor oil production is limited by the seed availability.

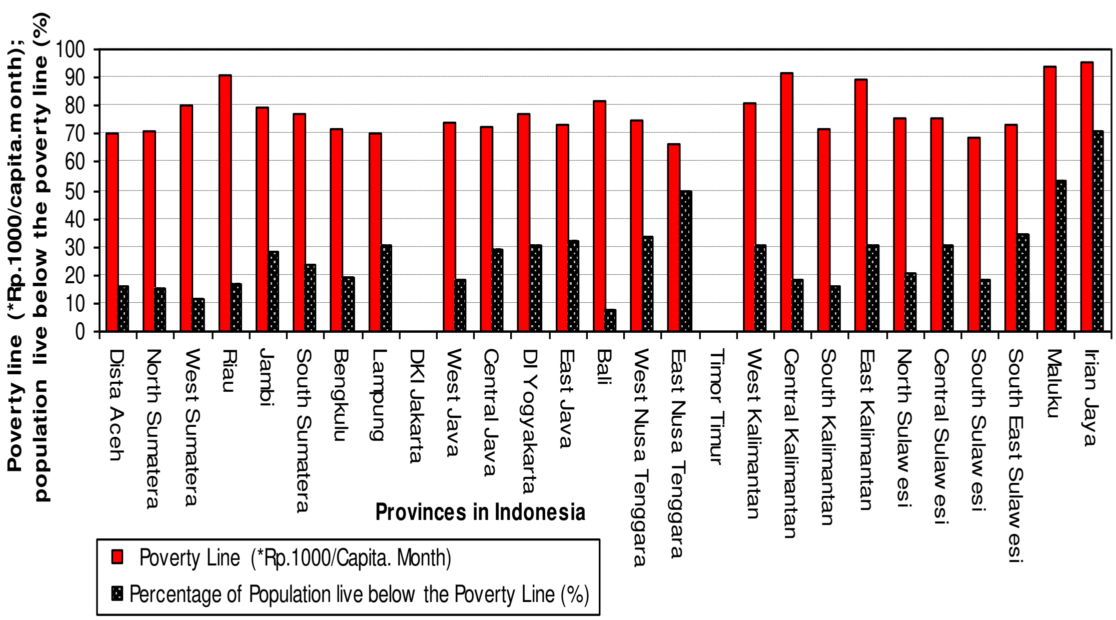

Fig. 4a ; Poverty line in rural areas by provinces in Indonesia, in 1999.
The poverty line in East Nusa Tenggara is the lowest, that is Rp 66,143.- and 49.39 % of population live below this poverty line, which means their incomes are below Rp. 66,143.-
Source: Statistik Indonesia 1999, BPS (2000, p597). Note: US$ 1 = Rp 8241 per 10 June 2003

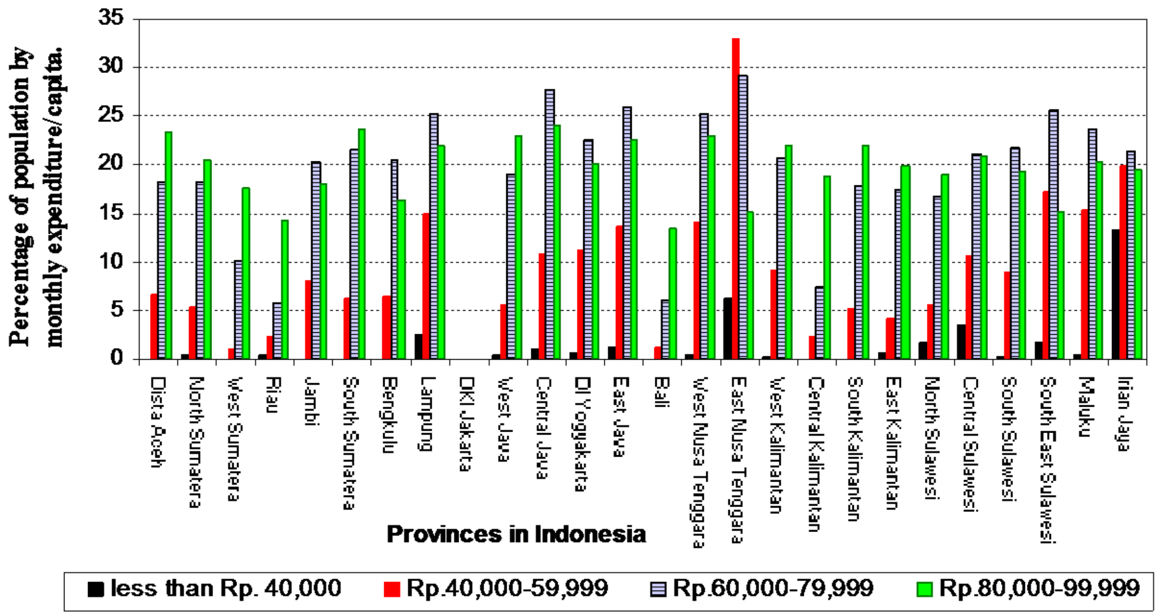

Fig. 4b Percentage distribution of population by monthly expenditure per capita, in rural areas of various provinces in Indonesia, per 1999. Only 4 expenditure classes until Rp. 99,999.- are shown.
Source: Statistik Indonesia 1999, BPS (2000: p.528).
In East Nusa Tenggara, 32.98% of the villagers spend Rp. 40,000-Rp. 59,000 in a month.

4. CONVERSION OF CRITICAL LANDS TO A GREEN ENERGY RESOURCE.

Jatropha curcas plantations yield over long periods of time and yields vary from 0.5 to 12 tons per hectare annually depended on soil and rainfall conditions (Makkar and Becker, 1999).
In India, jatropha curcas give 4 tons seeds/hectare/year and 5-6 tons bio-residue/hectare/year.
By transesterification, these seeds able to give 2 tons of bio-diesel /hectare/year (Fiodl and Eder, 1997). If the cost of curcas-diesel production by transesterification is approximately same as that of petroleum diesel, the cost of curcas-diesel production should be as low as 11.91-16.59 Rs per liter (Suman, 2004). His calculation uses assumption that the seed contains 35% oil and oil extraction will be 91-92%.

Suman (2004) gives a comparison to coconut trees that give 10000-30000 nuts/year/hectare plus residues of 5-7 tons shells and 8-10 tons fronds/hectare/year. The net revenue from one hectare of coconut plantation is 50,000-120,000 Rs (1250 - 3000 US$) for the food product, plus 15,000 – 20,000 Rs. (400 to 500 US$) equivalent of residues annually. Among the bio-oils, palm oil is energetically most promising, however it is edible therefore it is not to be used for engine.

In order to expand a rehabilitation program of the critical lands of Indonesia, an agro forestry crop such as jatropha curcas is proposed. Since Indonesia climate consist of dry and wet season, we assume that we could harvest only half of that harvested in India (minimum scenario), that is 2 tons seeds/hectare/year and 3 tons bio-residue/hectare/years.

If we use 50% of the critical lands in East Java (601,189 ha), East Nusa Tenggara (678,378 ha), West Nusa Tenggara (189,349 ha) and South Sulawesi (516,401 ha) for planting JC, we could harvest (2 tons seeds x 1,985,317 ha =) 3,970,634 tons seeds/hectare/year and 5,955,951 tons bio-residue/hectare/years. These seeds will give 1,985,317 tons of curcas oil.

The current price of diesel oil for transportation is partly subsidized. If the unsubsidized diesel oil price is assumed Rp.3000/kg and this price is equal to the production price of transesterified curcas oil then this program could generate cash outcome of 6 triliun rupiah if assured supply of jatropha seeds is ensured. The other advantage is the solid bio-residues can be used as intake for a gasification based on the compression ignition engine to produce electricity.

Curcas oil is a better alternative for kerosene lamp as it burns without emitting smoke.

Table 2a Properties comparison of Jatropha Curcas oil and of Diesel oil.
Source: Reyadh (2004)

Standard specification	Jatropha Curcas oil	Diesel
Flash point (°C)	110	50
Solidfying Point (°C)	2.0	0.14
Distillation (°C)	284 - 295	350
Kinematics Viscosity (cs)	50.73	2.7 - up
Calorific value (kcal/kg)	9470	10170
Pour point (°C)	8	10
Colour	4.0	4 or less
Viscosity of "Fatty acid" at 30^{o}C (cp)	52.6	3.60
Specific gravity 15 °C and 4 °C	0.917 and 0.923	0.841 and 0.85
Refractive Index at 30°C	1.47	--
Cetane Value at 38°C	51.0	47.8 - 59
Sulfur (%)	0.13 - 0.16	<1.2
Carbon residue (%)	0.64	< 0.15
Saponification Value	188 - 198	--
Iodine Value	90.8 -112.5	--
Acid Value	1.0 - 38.2	--
Palmitic acid (%)	4.2	--
Stearic acid (%)	6.9	--
Oleic acid (%)	43.1	--
Linoleic acid (%)	34.3	--
Other acids (%)	1.4	--

Note: The parameters of jatropha curcas oils presented in **Table 2a** are similar to the biodiesel from rapeseed oil currently used widely in Europe.

5. SUGGESTION.

The economic use of curcas oil as fuel (direct or as bio-diesel) would depend on the level of rural condition. Transesterification process has been known and made raw oil to be a good bio-diesel that can be used safely in reciprocating engines of a small electric generation and in gas turbine engines of vehicle. However, the limited facilities in remote rural area might leads to a "forced used" raw curcas oil in reciprocating engines of a small electric generation, therefore need to document the use of raw curcas oil in the engine to investigate engine life span. Until a further result is obtained, cleaning the injector periodically is suggested to avoid unexpected gumming.

Various species of Jatropha trees are not well accounted in Indonesia, therefore it is important to build a national database and methods of plantation of the existing varieties of Jatropha and documented its oil content.
Further works that need to be courage are:

- The selection of the species for plantation based on agro-technical considerations.
- Need to find out the cheapest way to avoid deceases in big plantation of energy-species trees.
- Need to organize supply of the propagation material.
- Need to guide the farmers regarding cultivation practices.
- Need to investigate an affordable technology for post-harvest storage.
- Need to transfer this knowledge widely to the farmers.
- Need to develop a simple protocol for extraction the bio-oil.
- Increase an effort to searching the cheapest extraction equipment and to investigate the simplest process of getting as much oil as possible.
- Fulfilling the energy needs in the country with a perennial shortage of electricity will need to develop a simple process to get diesel oil from raw curcas oil to drive reciprocating engines of a small electric generation and in gas turbine engines of vehicle.
- Need to establish a body with the tasks to organize harvesting and marketing of this agro product, to organize setting up of appropriate processing units, to help and guide the farmers in procurement of loans and to stand guarantee for repayment of loans;

The energy-specie tree plantation under rehabilitation program will contribute to reduce critical lands in Indonesia. The production capacity is flexible made the planting program easily match to the existing funding. This bio energy scenario provides a contribution to all energy markets (heat power, transport fuels, traditional lighting) therefore gives a chance to secure future energy supply. However, it requires governmental interventions involving the Ministry of Energy, the Ministry of Agriculture, the Ministry of Forests and the Ministry of Developing Disadvantaged Areas (PDT). Shifting a small portion of present oil-subsidies to this energy crops development could be sufficient for stimulating a large-scale deployment of bio-diesel.
Bringing engineering industries, the local government and private sector such as PT PLN would be vital to develop this energy security scenario for barren and remote area of Indonesia.
As the initial role is farmers, therefore national campaign to disseminate this national energy security scenario should be set out for a greater awareness and actions.

Table 2b Some important parameters of raw and transesterified jatropha oil

Parameter	Jatropha Oil Raw	Jatropha Oil Transesterified	E DIN 51606 standard
Density (g cm^{-3} at 20°C)	0,920	0,879	0.875 - 0.890
Flash Point (°C)	236	191	> 110
Cetane no. (ISO 5165)	23-41	51	> 49
Viscosity (mm^2/s at 30°C)	52	4.84	3.5 - 5 (40°C)
Neutralisation number (mg KOH/g)	0.92	0.24	< 0.50
Total glycerine (%)	-	0.088	< 0.250
Free glycerine (%)	-	0.015	< 0.02
Phosphorus (ppm)	290	17.5*	<10
Sulphated ash (%)	-	0.014	< 0.03
Methanol (%)	-	0.06	< 0.3
Source: Foidl et al., 1996; * negligible when de-gummed oil is used			

Table 3 Jatropha Curcas Oil properties compare to other non-edible oils. Source: Radhakrishna (2004).

Property	No. 2 Diesel	Curcas oil	Castor oil	Pongomia oil
Viscosity at 30°C (cp)	3.6	52.5	550	15
Specific gravity at 15°C	0.85	0.92	0.90	0.87
Carbon Residue (%)	< 0.15	~0.64	<0.50	~0.50
Calorific Value (MJ/ kg)	40-44	37-38	36-37	37-38

Specie of seed	Oil fraction (%)	Current Existing Estimation (million tons /yr)	Oil Tons/hectare/year
Ricinus comunis	45 – 50	0.25	0.5-1.0
Jatropha	40 – 60	0.20	2.0-3.0
Mohua	35 – 40	0.20	1.0-4.0
Sal	10 – 12	0.20	1.0-2.0
Linseed	35 – 45	0.15	0.5-1.0
Neem	20 – 30	0.10	2.0-3.0
Pongomia	30 – 40	0.06	2.0-4.0

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